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Reproductive biology of the common carp (*Cyprinus carpio* Linnaeus, 1758) in Marmara Lake, Western Anatolia, Turkey

Marmara Gölü (Batı Anadolu/Türkiye)'nde sazanın (*Cyprinus carpio* Linnaeus, 1758) üreme biyolojisi

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Hakkı DERELİ[1,*], Turhan KEBAPÇIOĞLU[2], Yusuf ŞEN[3]

[1] *Department of Fisheries and Fish Processing Technology, Faculty of Fisheries, İzmir Katip Çelebi University, Turkey*

[2] *Department of Recreation Management, Manavgat Tourism Faculty, Akdeniz University, Turkey*

[3] *Department of Marine Science and Limnology, Faculty of Marine Science and Technology, Çanakkale Onsekiz Mart University, Turkey*

ABSTRACT

There is a knowledge gap in some lakes of Turkey regarding the reproductive biology of the common carp (*Cyprinus carpio* Linnaeus, 1758), a very important freshwater commercial species. This study aims to determine for the first time the spawning period and length at first maturity (Lm_{50}) of common carp in Marmara Lake in Western Turkey. A total of 650 individuals were sampled between December 2015 and November 2016. The overall sex ratio (♂:♀) was 0.88:1 which is no significantly different from the balanced ratio of 1:1 ($p>0.05$). The spawning period peaked in February and continued until May. Lm_{50} was estimated as 43.7 cm and 39.6 cm for females and males, respectively. This study also presented some reproductive characteristics of common carp in the lake from the westernmost point for Anatolia.

Keywords: Length at first maturity, Spawning period, Maturity stages, Gonadosomatic index, Condition factor

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[*](corresponding author)
E-mail: hakkidereli@gmail.com

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ÖZET

Önemli bir tatlı su ticari türü olan sazan balığının (*Cyprinus carpio* Linnaeus, 1758) üreme biyolojisi konusunda Türkiye'nin bazı gölleri için bilgi eksikliği bulunmaktadır. Bu çalışma, Türkiye'nin batısında yer alan Marmara Gölü'ndeki sazan balıklarının yumurtlama periyodu ve ilk olgunluk boyunu (Lm_{50}) ilk kez belirlemeyi amaçlamaktadır. Aralık 2015 ile Kasım 2016 arasında toplam 650 balık örneklenmiştir. Cinsiyet oranı (♂:♀) 0,88:1'dir ve teorik 1:1 oranından önemli ölçüde farklı değildir ($p>0,05$). Yumurtlama dönemi Şubat ayında zirve yapmakta ve Mayıs ayına kadar devam etmektedir. Lm_{50}, dişiler ve erkekler için sırasıyla 43,7 cm ve 39,6 cm olarak belirlenmiştir. Bu çalışma aynı zamanda göllerdeki sazan balıklarının bazı üreme özelliklerini Anadolu'nun en batı noktasından ortaya koymuştur.

Anahtar sözcükler: İlk olgunluk boyu, Yumurtlama periyodu, Olgunluk safhaları, Gonadosomatik indeks, Kondüsyon faktörü

1. INTRODUCTION

Determining the reproductive biology of fish is of great importance in terms of fisheries management as well as filling the gap in fisheries basic sciences. Identifying reproductive characteristics of fish in each habitat is essential for successful fisheries management, since these characteristics may vary spatially (Karataş *et al.*, 2010).

Reproductive biology information, such as spawning period and length at first maturity (Lm_{50}), guides when and at what size target species should be caught for sustainable fisheries. It is a common fisheries management application that the fish are not caught during spawning periods, in other words, these periods are declared as the closed season. Technical measures such as minimum landing size and catch amount limitations are based on sexual maturity information (Avşar, 2005). Based on these data, fishing gears are arranged in such a way as to allow the juveniles to escape (Armstrong *et al.*, 1990).

Sustainable fisheries management is also required for common carp (*Cyprinus carpio* Linnaeus, 1758), a very important freshwater commercial species, whose catch has decreased by 76% from 12,058 tonnes to 2,893 tonnes in the last decade (from 2010 to 2020) in Turkey (TUIK, 2022).

The common carp is native to rivers draining to the Black, Caspian and Aral Sea in Europe and Asia but has been introduced into several freshwater ecosystems world-wide (Kottelat and Freyhof, 2007; Froese and Pauly, 2022). *C. carpio* is a benthic omnivore, both adults and juveniles feed on a variety of benthic organisms and plant material. Breeds along shores or in backwaters. Adults often undertake considerable spawning migration to suitable backwaters and flooded meadows (Kottelat and Freyhof, 2007). In temperate environments, it matures in 3-5 years (Adamek and Pistelok, 1991) and spawns in early summer and spring (Oyugi *et al.*, 2011).

There is a knowledge gap in some lakes/reservoirs of Turkey regarding the reproductive biology of the *C. carpio*. Studies mostly focused on lakes and reservoirs in Central Anatolia (Düzgüneş, 1985; Çetinkaya, 1992; Bircan, 1993; Yılmaz, 1994; Bircan and Erdem, 1997; Yerli and Zengin, 1998; Karataş, 2000; Balık and Çubuk, 2001; Doğan, 2001; Özyurt and Avşar, 2001; Şen, 2001; Yılmaz and Gül, 2002; Kılıç, 2003; Karataş and Sezer, 2005; Güç, 2006; Kırankaya, 2007; Mert *et al.*, 2008). There are no studies on the lakes, except carried out in 2 reservoirs (Kemer and Bayramiç Reservoirs) in Western Anatolia (Özcan and Balık, 2007; Çolakoğlu and Akyurt, 2013).

Marmara Lake, which is an alluvial set lake with an average depth of 3-4 m, is located in Western Anatolia, Turkey (Figure 1). This lake is an important carp habitat and fishing area for which reproductive biology have not been done before. Therefore, this study aims to determine the spawning period and Lm_{50} of common carp in Marmara Lake.

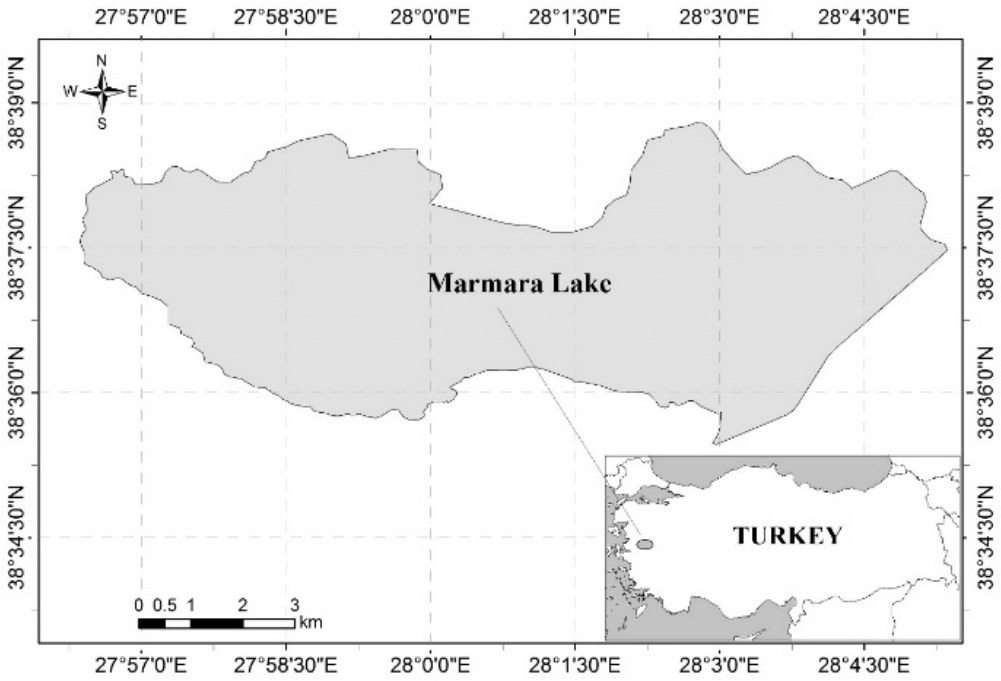

Figure 1. Study area (Marmara Lake).

2. MATERIAL AND METHOD

Monthly sampling was carried out by local commercial fishers in different areas of the Marmara Lake from December 2015 to November 2016. Ten types of multifilament gillnets (with 70, 75, 80, 90, 100 mm nominal mesh size/bar length and 210d/2 and 210d/3 twine thicknesses) and beach seine (9 mm mesh size) were used for sampling.

Fish samples were immediately transferred to laboratory in cooler boxes. The total length (L), body weight (W) and gonad weight (Gw) were measured to the nearest 0.1 cm, 1 g and 0.01 g, respectively. Sex was determined by macroscopic observation of gonads. Sex ratios were compared using the chi-square (χ^2) test in order to verify whether the proportion of males and females differed from the expected ratio 1:1 (Zar, 1999).

Sexual maturity stages were determined with the five-staged maturity scale (Holden and Raitt, 1974): stage I (immature) – gonads are very small and testis is whitish; stage II (maturing and recovering spent) – gonads are small, dully transparent and pinkish-whitish; stage III (ripening) – gonads are enlarged, ovary is pinkish-yellow with granular appearance and testis is whitish to creamy; no transparent ova; stage IV (ripe) – gonads are considerably enlarged, ovary is large and transparent, orange-pink with conspicuous superficial blood vessels; ripe ova are visible; testis is whitish-creamy, soft; and stage V (spent) – gonads are shortened, walls loose, flabby, empty, dark red with traces of sperm or ova.

To identify spawning period, the condition factor (CF) and the Gonadosomatic index (GSI) were estimated for both sexes using

$$\boldsymbol{CF = \frac{W \times 100}{L^3}} \quad (1)$$

and

$$GSI = \frac{Gw}{W \times 100} \quad (2)$$

where Gw and W are the gonad and body weights for both sexes, respectively (Ricker, 1975; Bagenal and Tesch, 1978).

Lm_{50} was examined for both sexes using samples in February and spring (March, April and May) for female, where GSI values and the proportion of mature individuals (stages III, IV and V)

increased, and samples in winter (December, January, February) and spring for male. The mature (stages III, IV and V) and the immature individuals (stages I and II) were proportioned for each size group with 1 cm intervals. Lm_{50} was estimated by modeling the proportion of mature individuals to their respective length classes based on the following logistic function:

$$\boldsymbol{P = \frac{1}{1+e^{-a(L-b)}}} \quad (3)$$

where P = percentage of mature fish by length class, L = total length class, a and b are model coefficients. This analysis allows the estimation of the 95% confidence intervals for Lm_{50}. The Lm_{50} was estimated using the equation:

$$\boldsymbol{Lm_{50} = -\frac{a}{b}} \quad (4)$$

Data were analysed using "Solver" in Microsoft-Excel programme (Tokai, 1997).

3. RESULTS

A total of 650 common carp individuals were examined during the study period. Of the entire sample, 328 (50.5%) of the samples were females, 289 (44.5%) were males and 33 (5%) were of undetermined sex. Range and mean values of lengths and weights for female, male and all individuals were presented in Table 1. Length and weight values (minimum, maximum and mean) were higher in females than males. The overall sex ratio (♂:♀) was 0.88:1, which is no significantly different from the theoretical ratio of 1:1 (χ^2: 2.465, df: 1, $p > 0.05$). GSI values reached peaked for females in February (8.29) and decreased afterwards until August, and had a second smaller peak in December. Males also peaked in December (4.26), decreased afterwards until July. CF values peaked in May (♀: 1.67; ♂: 1.72) in both female and male individuals. Afterwards, the values decreased and reached their lowest value in February in both female (1.30) and male (1.27) individuals (Figure 2).

When the monthly changes of maturity stage and GSI values of females were examined, the rate of ripening (stage 3) and ripe (stage 4) individuals also increased in February, with peak GSI values. High percentages of ripe and spent (stage 5) individuals were observed from April to June when GSI was in decline (Figure 3).

In males, the rate of ripening and ripe individuals also increased since August when GSI values started to rise and reached the highest rate in March. The rate of spent male individuals from April to June increased (Figure 4).

Lm_{50} were found to be 43.7 cm and 39.6 cm for females and males, respectively (Figure 5).

Table 1. Total length and weight values of common carp (n= number of fish sampled, min= minimum, max= maximum, SE= standard error)

		Total length (cm)			Weight (kg)		
	n	min	max	mean ±SE	min	max	mean ±SE
Female	328	29.2	98.0	51.65±0.77	0.384	13.950	2.474±0.13
Male	289	24.3	82.0	45.68±0.48	0.228	8.200	1.565±0.07
All	650	24.3	98.0	48.71±0.47	0.228	13.950	2.027±0.08

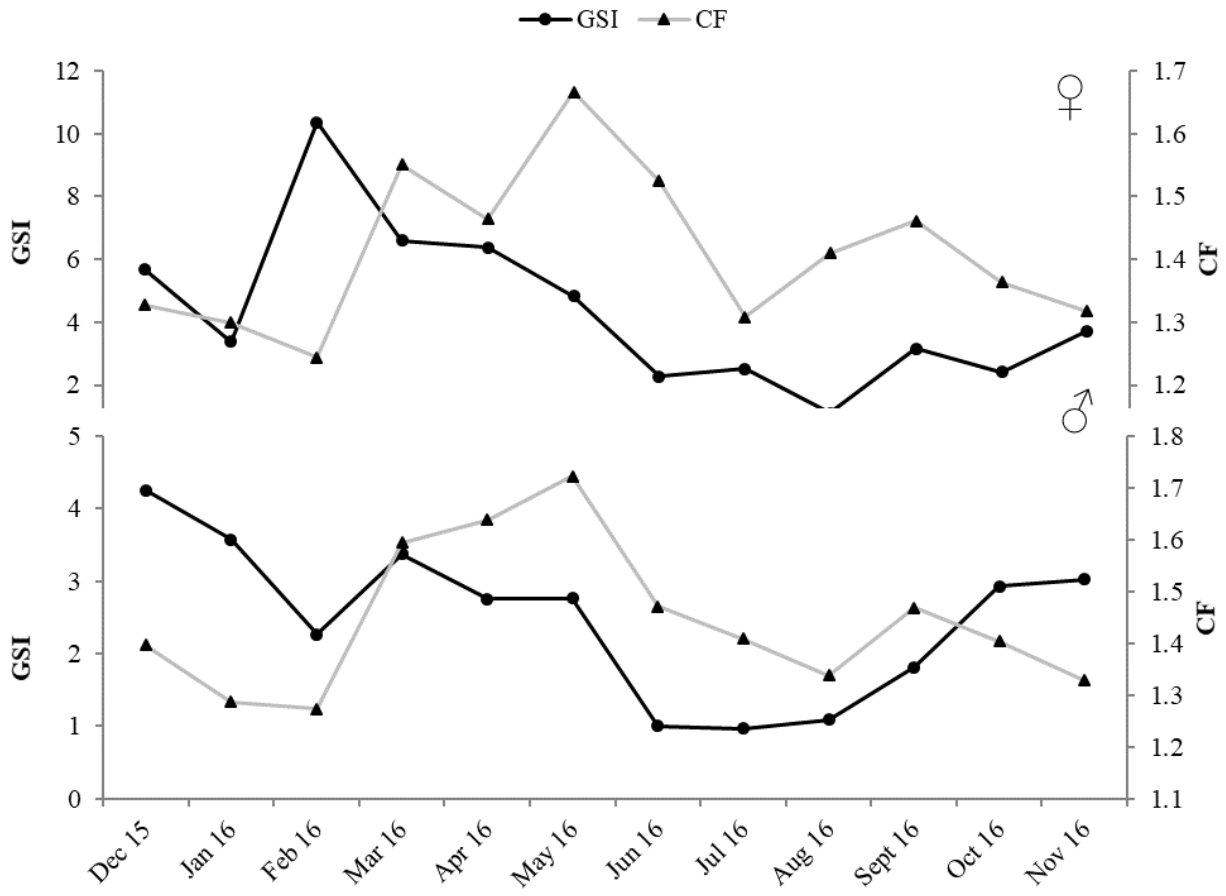

Figure 2. Gonadosomatic index (GSI) and condition factor (CF) trends for females (♀) and males (♂) over a one-year period.

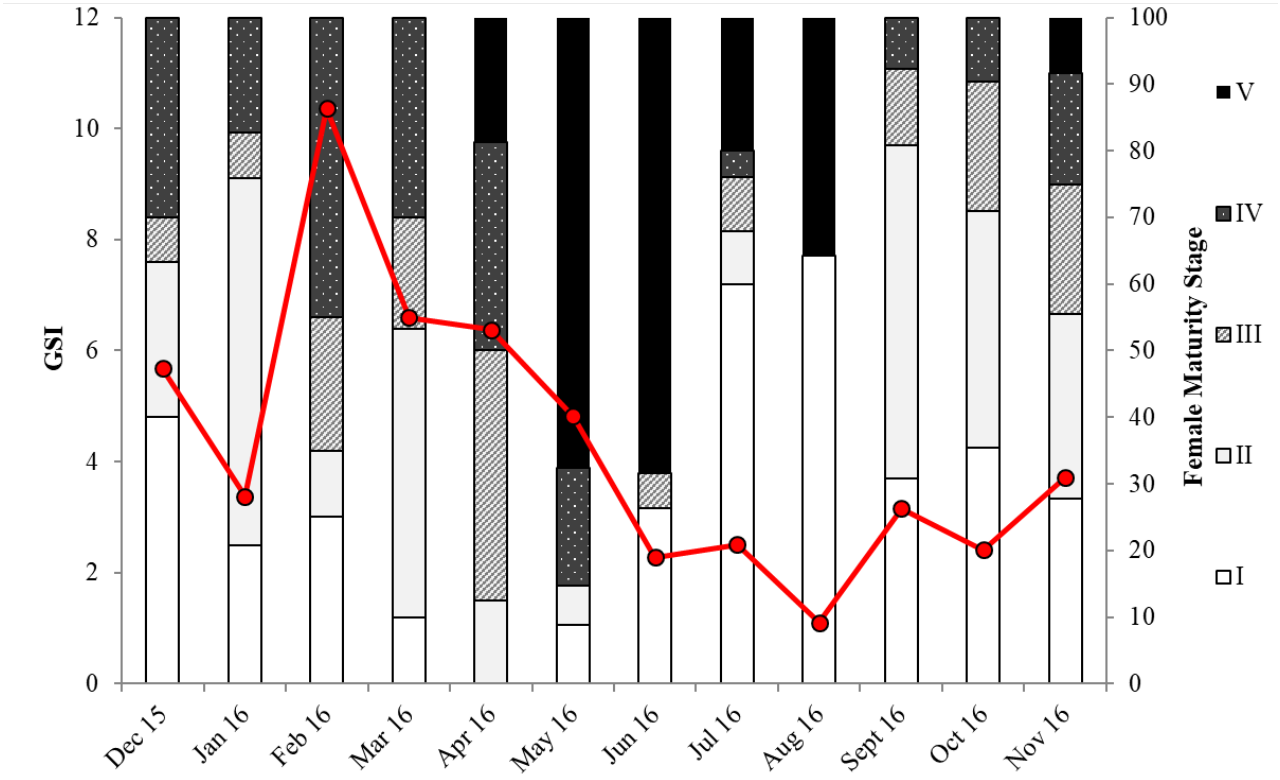

Figure 3. Monthly variations in female maturity stages (bars) and gonadosomatic index (GSI) values (red line).

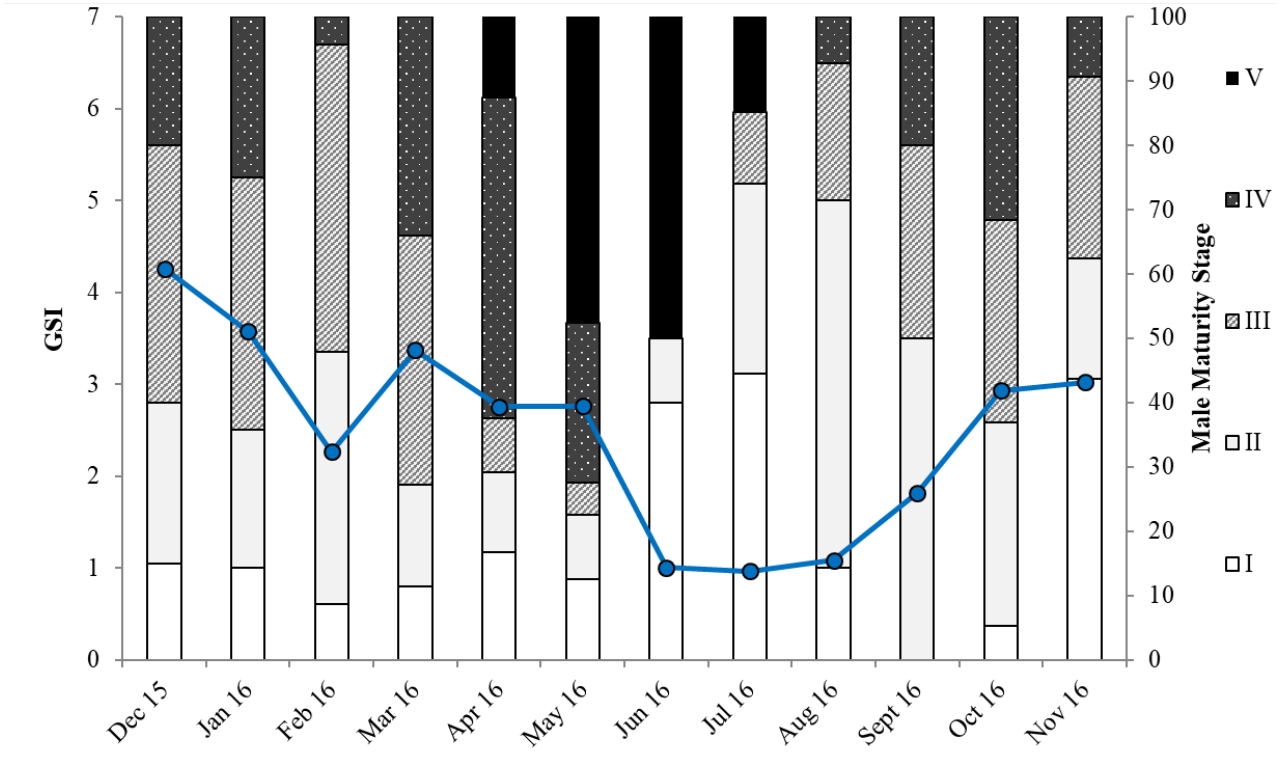

Figure 4. Monthly variations in male maturity stages (bars) and gonadosomatic index (GSI) values (blue line).

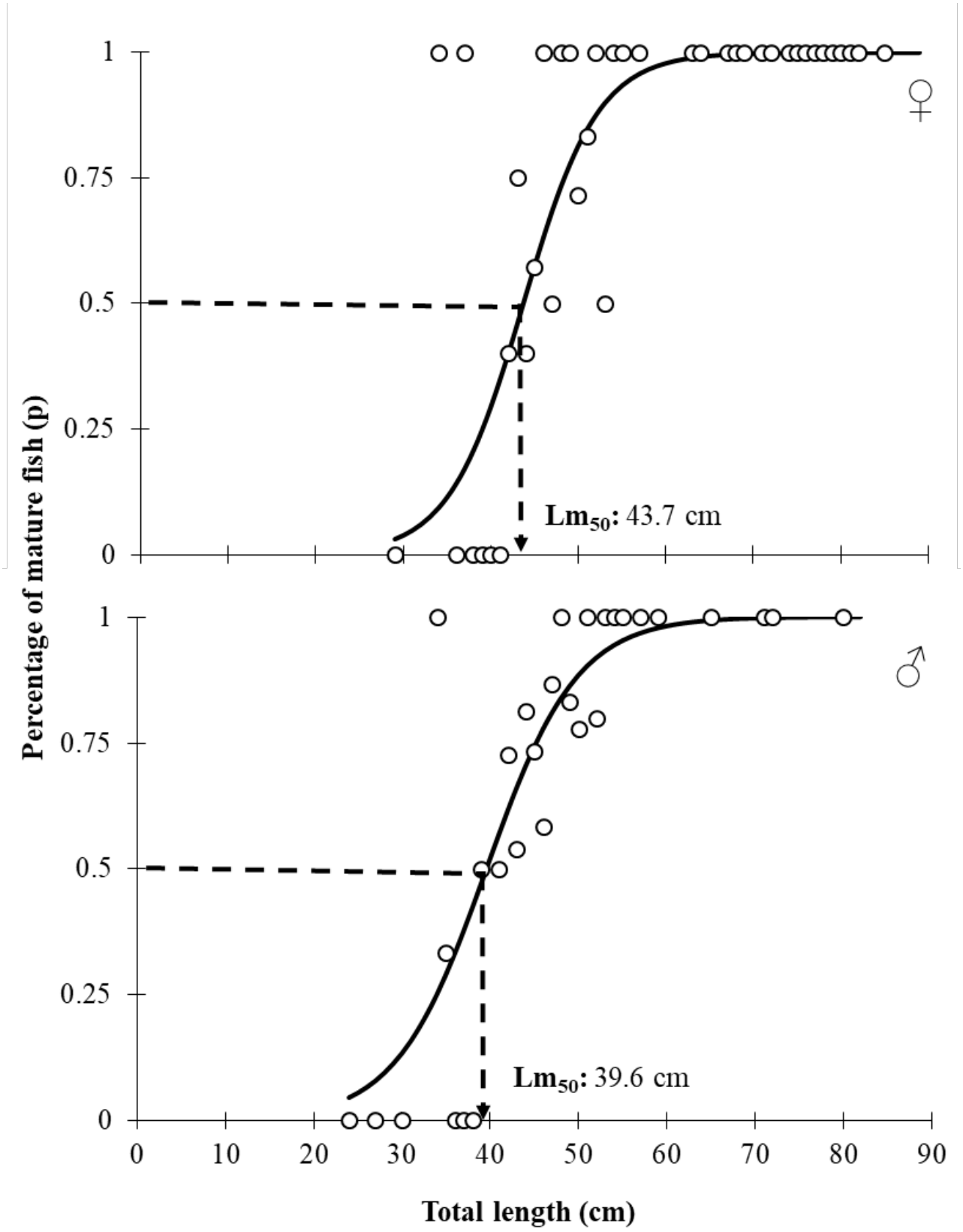

Figure 5. Length at first maturity (Lm_{50}) for females (♀) and males (♂). n= 100 females and 179 males.

4. DISCUSSIONS

The findings regarding the reproductive characteristics of common carp in this study and previous studies conducted in other localities of Turkey were presented in Table 2. In most of these studies, it was reported that females were proportionally dominant, similar to the present study. Although sex ratios are often treated as more or less fixed population characteristics, current theoretical evidence suggests that the sex ratio fluctuates under many conditions and the amplitude of these variations may be significant (Pettersson *et al.*, 2004). Although there is no statistical difference, the proportional predominance of females, which play a key role in the continuity of the population, should be seen as an advantage for the stocks in Marmara Lake. In these studies, it has been reported that the spawning period of *C. carpio* usually start in April-May. In addition, Vilizzi *et al.* (2014) examined 30 studies on the reproduction of common carp across 26 waterbodies in Anatolia (Turkey) and emphasized that the reproductive features of common carp are largely homogeneous across Anatolia, and the spawning of the species begins between March and June, and lasts for 2–7 months. In this study, according to the GSI and gonadal development results, the spawning period of the common carp is seen in February-May as annual spawning. The fish utilize a considerable part of their energy reserves on gonadal development during the spawning season, which is reflected by their inverse relationship of their GSI with their condition factor (Avşar, 2005), also confirming the spawning season. To better understand the exact duration of the spawning season, gonad samples would need to be collected at least weekly for the year and the eggs examined under histological slides to locate postovulatory follicles. The spawning periods determined in this study are not similar to other studies that mostly show the late spring-summer period. It is thought that the difference in this study may be due to the shallowness of the lake and, accordingly, the faster change in water temperature and earlier stimulation for spawning (Bondarev *et al.*, 2019). In addition to depth and temperature, biodiversity (fish species and other species), nutritional status, competition, pollution, precipitation and fisheries activities in Marmara Lake are also factors that can affect the lake's ecosystem and affect reproduction.

The seasonal ban for the province of Manisa, where Marmara Lake is located, was set for 15 March until 15 June in the previous regulation, active from 2016-2020 (Official Gazette, 2016), which was amended to 1 March-1 June in the latest regulation for 2020-2024 (Official Gazette, 2020). The current seasonal closure does protect the spring, but does not capture the February, and is hereby recommended to include February in the next updated regulations forecasted for late 2024.

Lm_{50} for males (39.6 cm) was found to be lower than females (43.7 cm) in this study. Other studies, also support that males can mature at smaller sizes than females (Avşar, 2005; Karataş *et al.,* 2010). The female Lm_{50} value being 3.7 cm above the MLS of 40 cm, shows that the MLS size is inadequate. Lm values are usually set at the minimum length of maturity for females, thus allowing the stock to at least reproduce once before catching them (Yildiz and Ulman, 2020). The Lm_{50} values in this study were higher than the values determined by Özyurt and Avşar (2001) as 28.8 cm for females and 28 cm for males in the Seyhan Dam Lake in south-eastern Turkey. It could be the fish triggered by water temperature changes. Since the Lm_{50} values were determined as fork length in the other two studies (Yerli and Zengin, 1998; Şen, 2001), they could not be compared with our values (Table 2).

Table 2. Sex ratio, spawning season and length at first maturity of *C. carpio* in different locations in Turkey (♂: male, ♀: female, *Fork length)

Author	Sex ratio (♂:♀)	Lm_{50} (cm)	Spawning period	Locality
Düzgüneş (1985)	0.95:1	-	May-Aug	Mogan Lake
Çetinkaya (1992)	0.86:1	-	May-Jul	Akşehir Lake
Bircan (1993)	0.97:1	-	Apr-Jul	Bafra Balık Lakes
Yılmaz (1994)	1.01:1	-	May-Aug	Kapulukaya Reservoir
Bircan and Erdem (1997)	0.85:1	-	Apr-Oct	Altınkaya Reservoir
Yerli and Zengin (1998)	-	♂: 26.2* ♀: 31.4*	-	Çıldır Lake
Karataş (2000)	0.84:1	-	Mar-Apr	Kazova Kaz Lake
Balık and Çubuk (2001)	0.87:1	-	Apr-May	Karacaören I Reservoir
Doğan (2001)	1.76:1	-	May-Jun	Çamlıdere Reservoir
Özyurt and Avşar (2001)	-	♂: 28.0 ♀: 28.8	May-Jul	Seyhan Dam Lake
Şen (2001)	1.68:1	♂: 29.0* ♀: 39.0*	Jun-Jul	Nazik Lake
Yılmaz and Gül (2002)	1.08:1	-	May-Jul	Hirfanlı Reservoir
Kılıç (2003)	-	-	May-Jul	Yeniçağa Lake
Karataş and Sezer (2005)	0.71:1	-	Jun-Aug	Almus Reservoir
Güç (2006)	1.14:1	-	-	Keban Reservoir
Kırankaya (2007)	0.97:1	-	Apr-Jul	Gelingüllü Reservoir
Özcan and Balık (2007)	1.14:1	-	-	Kemer Reservoir
Mert *et al*. (2008)	1.03:1	-	Jun-Jul	Apa Reservoir
Çolakoğlu and Akyurt (2013)	0.86:1	-	May-Jul	Bayramiç Reservoir
Present study	0.88:1	♂: 39.6 ♀: 43.7	Feb-May	Marmara Lake

5. CONCLUSION

In this study, the spawning period of common carp peaked in February and continued until May in Marmara Lake in Western Anatolia. It was determined that the carp began to spawn in this lake earlier than in other parts of Anatolia. Lm_{50} was 43.7 cm and 39.6 cm for females and males, respectively. With this study, findings regarding the reproductive characteristics of carp were given from a lake in the westernmost part of Anatolia.

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AUTHORSHIP CONTRIBUTION STATEMENT

Hakkı DERELİ: Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Writing-Review and Editing, Software, Visualization, Project Administration. **Turhan KEBAPÇIOĞLU:** Methodology, Formal Analysis, Writing-Review and Editing. **Yusuf ŞEN:** Methodology, Formal Analysis, Writing-Review and Editing, Visualization.

CONFLICT OF INTERESTS

The authors declare that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

The authors declare that this study was conducted in accordance with ethics committee procedures of human or animal experiments.

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ORCID IDs

Hakkı DERELİ:
https://orcid.org/0000-0002-1240-8922
Turhan KEBAPÇIOĞLU:
https://orcid.org/0000-0002-6230-1744
Yusuf ŞEN:
https://orcid.org/0000-0002-0595-4618

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